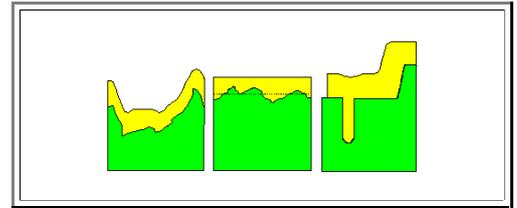


### 3.2.4 Summary to: 3.2 Mechanical Properties

Thin films have other spatial properties besides their thickness, i.e. roughness

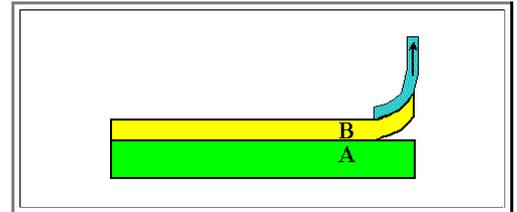
- Interface roughness and surface roughness  $R$  defined by their "root mean square".

$$R = \left( \frac{1}{N} \sum_{i=1}^N z_i^2 \right)^{1/2}$$



Useable thin films adhere to their substrate.

- A direct measure of adhesion is the interfacial energy  $\gamma_{AB}$  between film **A** and substrate **B**.
- The phase diagram provides some guideline. Complete miscibility = good adhesion, (eutectic) decomposition = (?) low adhesion. Calculations of  $\gamma$  are difficult.
- Full adhesion can only be obtained for films *grown* on a substrate. Adhesion energies can be measured.



Generally, there will be stress  $\sigma$  and strain  $\epsilon$  in a thin film and its substrate.

- A major source of strain is the difference of the thermal expansion coefficients  $\alpha$

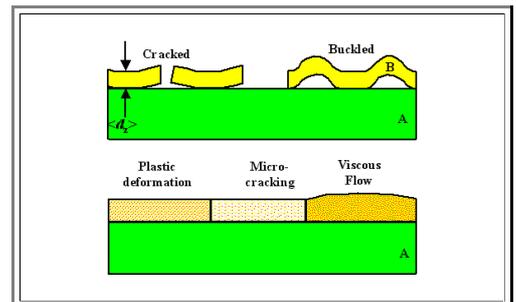
$$\epsilon_{TF} = \Delta T \cdot \Delta \alpha$$

$$\sigma_{TF} = Y \cdot \Delta T \cdot \Delta \alpha$$

**Stress and strain in thin films can be large and problematic!**

Stress in thin films may relax by many mechanisms; and this might be good or bad:

- Cracking or buckling
  - Plastic deformation
  - Viscous flow
  - Diffusion
  - Bending of the whole system (Warpage)
- Warpage can be a serious problem in semiconductor technology.



**Exercise 3.2-1**  
All Questions to 3.2